Hydrographic Survey Proposal for Dredging Work
Final Report

ESSE 4650 W22

Ryan Nguyen, Nadine Norman, Erin Corrado

EXECUTIVE SUMMARY

The purpose of this report is to present a project proposal for a hydrography survey to be conducted at the Hamilton Harbour for dredging purposes. The Sea Monkeys corporation will be responsible for the hydrographic survey. The report briefly goes through the background of the company and focuses on the planning of the project. A set of three surveys shall be conducted, one before dredging commences, another midway through the dredging project and finally one at the end of the dredging project. Sea Monkeys shall provide refined and processed bathymetric products obtained from the survey. These shall be used by the dredging company to properly plan their project. The report includes the various phases of the project development and provides some data about the Hamilton Harbour. It also enlights the data acquisition and analysis process and includes a budget meant to cater for the whole project.

Introduction

The Sea Monkeys cooperation was asked to present a project proposal for a hydrographic survey that will be conducted in Hamilton Harbour. The hydrographic survey to be conducted is meant for dredging purposes. The cooperation has assigned three of its best project designers to take up this proposal.

There shall be a total of three surveys conducted, an initial survey before the dredging operation starts, an intermediate survey to check the progress of the dredging operation and finally a third survey to ensure that the requirements have been met. This Proposal goes into detail about the procedures the company intends to take to complete all three surveys. It includes the logistics and costs for the whole operation.

Problem Statement

The purpose of this project is to successfully conduct three hydrographic surveys for the purpose of monitoring a dredging activity.

The Sea Monkeys cooperation is a relatively new company located in Markham Ontario. We generally provide services in the greater Toronto area but can extend our services beyond this area occasionally. Our staff mostly consists of licensed and experienced land surveyors with most of them being licensed Hydrographic surveyors as well.

Our previous projects included working for Dominion Gas to create reference plans for permanent and temporary easements as well as topographic surveys for the installation of pipelines. We have also conducted a hydrographic survey for the squareville conservation authority to determine the amount of sediment on the river bed which could potentially cause flooding. One of our major projects was the provision of survey services in the extension of subway services from Vaughan Metropolitan Center to Mount Pleasant Go Station in Brampton.

Dredging is very important for a couple of reasons, it can be used to clear sediments from the river bed thereby increasing or maintaining the water depth of navigation channels, anchorages, or berthing areas to ensure the safe passage of boats and ships. Vessels require a certain amount of water to be able to safely float and not touch the river bed.
Dredging is also important to reduce the contaminants in the river that may affect the river's flora and fauna. Previous dredging work has already been done at the Hamilton Harbour to remove toxic sediments from the seab

Project Plan

For this project, a survey of the lake bed in the Hamilton Harbour is being undertaken. There will be three surveys total, that will map the lake bed of the Harbour and its associated depth.

The first survey will be prior to the dredging project. Once the data from this is collected and processed, the dredging will begin, using the first survey's measurements as a base benchmark.

Three-quarters of the way through the dredging project, a 'check' survey will be performed, in order to chart the progress of the dredging project, and check that it is at/on track to meet the appropriate depth. Once the dredging is completed, a third survey for the project will be performed, in order to verify that the correct depth was reached. If it is not, the dredging will resume and another survey will be performed after this.

In terms of the equipment for this project, the following will be needed: boat, echo sounders, navigation tools (including those that run continuous checks to ensure that drift from current and waves are not causing the boat to go too far off of the planned path), and data processing tools.

The Hamilton Harbour is 21.5 km^2, and as such, no accommodations for crew would be needed on the boat, as they can return to shore at the end of each work day. An echo sounder on a boat was chosen over LiDAR on aircraft, as the Hamilton Harbour is highly polluted and this can cause the turbidity in the water to be high. High turbidity can negatively affect the accuracy of LiDAR surveys, and as such, sonar is favoured here.

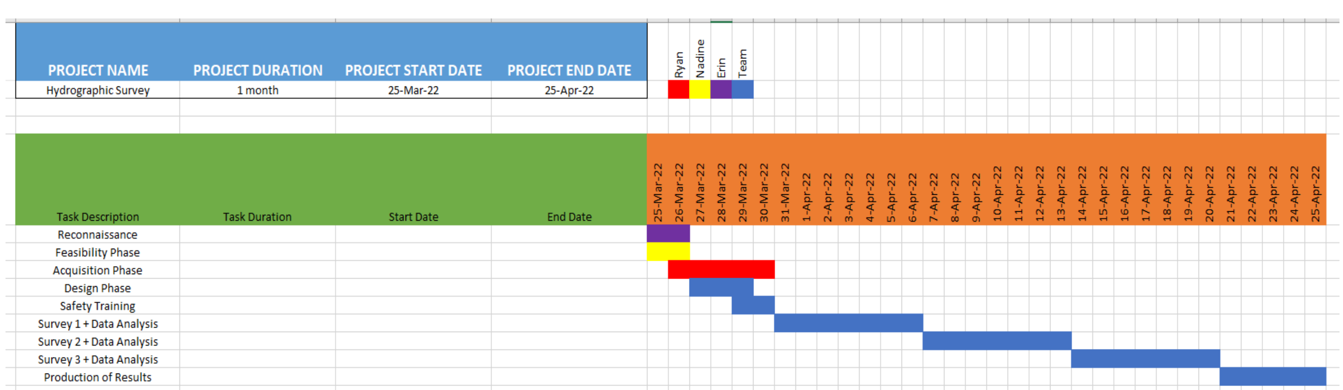
While an acoustic sweep system of single beam echo sounders could have been an option for a calm, shallow harbour, for this project, multi-beam systems were chosen, as the more complex profile it provides of the seafloor, (in this case, the harbour bottom), makes it better for the level of depth accuracy and detail needed for a dredging project. This technology will provide coverage across 100% of the lake bottom of the harbour at a high resolution. The accuracy for a dredging project in a shallow harbour, such as Hamilton Harbour, should be in the Exclusive Order (as per the CHS Survey Standards). This means a horizontal accuracy of 1m at a 95% confidence level, and a depth accuracy of a = 0.15m, b = 0.0075, where 'a' is the constant depth error, and 'b' is the factor of depth dependent error. In addition to using multi-beam echo sounders, since the accuracy of the survey is worse with a higher swath width, the swath width for the echo sounders in this project would be limited to 120 degrees maximum.

The Hamilton Harbour has a depth shallower than 100 metres, so the frequency of the Multibeam Echo Sounder will be higher than 200kHz.

Since multi-beam echo sounders will have more data, there will be more data processing needed throughout the project. A "collect-process-collect" methodology will be employed. This means that as the data is collected, it will be processed so that any areas with excessive outliers or possible errors or missing data can be re-surveyed in order to fix and fill in those gaps.

In addition, Sidescan Sonar will be used for imaging purposes. In order to have high resolution imagery, shorter pulses and narrower beam patterns will be used. In addition, the vessel speed and ping rate will be calculated in order to make sure no gaps occur in the collection (for example vessel moving too fast and moving past a point on the waterbed before it can be fully 'pinged').

<u>Project Schedule</u>



Design of Hydrographic Survey

Reconnaissance

This phase of the survey deals with information that is already established. This information can be acquired through research, provided by the client, and by observation. Key information about the Hamilton Harbour will be determined to understand its history. Acquiring a nautical map of the survey area is crucial to determine its area and depth that can be used as a reference for the project survey. A nautical map can be acquired online through GPS Nautical Charts [10]. The map should be used along with a map of the International Great Lakes Datums to determine reference benchmarks when beginning the survey [11]. This will help determine the position of the survey using GNSS positioning equipment. A tide table is also acquired to find the mean water level and tide heights on certain days with the addition of geoid reference models. The project sponsor may have some information regarding the survey project stemming from the goal of the dredging project. Visiting the survey area physically is important to visualize the water before collecting data on the boat. We can see how deep the water seems, noting possible entry and exit points when boarding the boat (this helps with designing the survey lines), and unique qualities of the harbour such as the Burlington Lift Bridge, a marsh location, and a blockade. It is noted that the Hamilton Harbour is found to have murky, polluted waters. Fortunately, the Hamilton Harbour is familiar territory to one of our crew members who is tasked with the reconnaissance.

Study Area

The study area will consist of the main portion of Hamilton Harbour, including the shipping ports, and extend out to the edge of the Burlington Canal on the harbour side. The marsh area on the North-Western side of the harbour, attached to the North end of what is known as Burlington Bay, will not be included, as the depth in this region is 3 feet or less. In addition, any area west of McQuesten High Level Bridge (Cootes Paradise) will not be included either.

In terms of the actual survey, the Hamilton Harbour is a main shipping port, and sees mostly commercial traffic in the area that would be surveyed. As such, the Harbour authorities are in charge of ensuring that shipping traffic is aware of other boats in their area and running the clearances for them. This port authority would be working with the survey team to run clearances. In addition, websites such as Marine Traffic will show where ships, (both commercial and large registered pleasure craft), are currently located: https://www.marinetraffic.com/en/ais/home/shipid:758239/zoom:15 Smaller boaters can use the harbour, but generally do so at their own risk, much as in other harbours such as Toronto Harbour.

The Burlington Lift Bridge, which is above the Burlington Canal portion of the Hamilton Harbour, is not currently encompassed by the current survey area draft plan, and as such, does not need to be taken into account, however, even in its default lowered position, it has a clearance of 5 metres which is high enough for most smaller craft to pass through (https://www.tpsgc-pwgsc.gc.ca/ontario/burlington-eng.html). In the event the survey scope was widened, the Burlington Canal was included, and also more than 5 metres of clearance was needed, the bridge is regularly lifted for shipping traffic - on-demand for large ships, and on every half hour for pleasure craft (https://www.tpsgc-pwgsc.gc.ca/ontario/burlington-eng.html).

Feasibility Phase

This phase involves discussing with the client on specifications of the project, researching required equipment needed for the project, and establishing a budget for the entirety of the project. We need to understand why this project is important to the project sponsor. What the purpose of the project is, what should the end result look like, and the commission are questions that will be discussed. As specified in the project manual, the client needs our company to conduct a hydrographic survey for a dredging project in the Hamilton Harbour that will span over a month. The hydrographic survey will reveal the depth and provide imagery of the seafloor to understand the dimensions of the water body for the dredging project. The project sponsor may also specify the horizontal and depth accuracies. It is assumed the standards is exclusive grade following the Canadian Hydrographic Survey [1] due to the survey area being in shallow waters. This survey grade results in a horizontal accuracy of 1m and vertical accuracy of 0.15m in depth error and 0.0075 for independent depth error with a 95% confidence level. Knowing the who, what, where, when, and how, we can understand what type of equipment is required for the project. Some examples of equipment needed for the survey is a boat rental, multi-beam echo sounders, IMU sensors, side-scan sonar for seabed imagery, laptop with necessary software, and dry suits. This list of equipment along with the commission of service will be used to develop a budget for the entirety of the project. The budget will cover the expenses of the project from the equipment, travel, payroll, and service. The list of equipment should be developed on the first day of planning to leave as much time as possible to acquire the equipment in case of delayed shipping times.

Acquisition Phase

During this phase, equipment, hardware and software, insurances, and vehicles are procured and ready for the survey. Equipment will be sought out and be given adequate time from the second day of planning until before the day of surveying. This allows for as much time to have equipment shipped in and finalize details with any rentals. Some of the equipment needed would be dry Suits and life ring buoys which would act as safety equipment in case any team member falls overboard. Multibeam Echo Sounder for recording depth measurements, a side-scan sonar for recording seabed imagery. A Boat to hold all crew members and equipment and a laptop to record data from echo sounders and side-scan sonar.

Dry suits and life ring buoys can be purchased at Dive World in Hamilton [2]. The multi-beam echo sounder and side-scan sonar equipment were obtained from Norbit [3] and Geo-matching. We already have a boat available but we will hire a boat captain as they have the most experience navigating a boat efficiently which will help stay accurately on our survey lines. The boat captain is familiar with the harbour and will be compensated for their service. We will be using CARIS HIPS and SIPS [6] software to process the multi-beam and imagery data as it is familiar software that we have used before.

Design Phase

This phase finalizes the design of the hydrographic survey and reviewing all acquired information. The multi-beam and side-scan sonar surveys can be done simultaneously as the multi-beam equipment can be attached to the boat itself and the side-scan sonar is clipped to the boat as a tow fish. Since the multi-beam echo sounder (Norbit Winghead i77h) has a shorter swath width than the side-scan sonar, the survey lines will be specified to meet the extent of the multi-beam echo sounder. The specifications show that the multibeam echo sounder has an effective 120° spread where the seabed is approximately 23m deep. This results in the horizontal footprint being approximately 80m wide.

[Figure 2 and 3] represent what the survey line and check line looks like for the hydrographic survey of Hamilton Harbour. The boat captain will follow these paths. The check lines are for quality assurance designed to cover the majority of survey lines twice and is believed to be where the main dredging project is located. It is approximately 77 km in total.

We decided to not survey the marsh area [Figure 4] due to it being unnavigable waters. We spaced out the survey lines adequately so that there is little overlapped coverage (approximately 10%). This is for quality control by recording extra measurements. The survey line [Figure 3] is designed so that it crosses the survey lines at least twice. The survey path is designed so that the survey goes perpendicular to the contour lines and then covering the rest of the water area [Figure 6]. The first half of the survey is uniform in line distance pacing back and forth until reaching certain sections of the harbour [Figure 5]. Due to the section being in the form of a triangle, the survey path is altered to cover the remaining area for both sections ending in the middle of the “section triangle”.

Safety Training

As hydrographers, we have completed the CIDCO certificate which is an International Hydrographic Organization (IHO) recognized course. This course allows us to contribute to hydrographic activities for companies and government agencies in accordance with industry quality standards [8]. The course details knowledge of marine environment and hydrographic operations, set-up of hydrographic equipment, execution of hydrographic surveys and data processing. It is encouraged that the team acknowledges boat safety in the case a life ring buoy is needed. Resources can be found on the Canadian Red Cross website [9].

Surveys 1, 2, 3

The surveys developed in the design phase will be conducted 3 times during the phases of the dredging project. We have allocated a week per each survey where the crew is given 5 days to conduct the measurements along (approximately 20 km per day), 1 day for quality control and assurance (check line and extra measurements), and 1 day to process the data. Operations of the survey will be approximately 7am-9pm where we account for an hour commute to and from survey site. The actual survey will be from 8am-8pm to maximize the time of sun.

The first survey will be conducted before the dredging project to understand what the water depth and imagery looks like before the operation. This data will show the dimension/area of where the dredging project can be operated.

The second survey will be conducted during the dredging project to understand if the seabed is being scooped out properly (not too much or too little). This ensures that the dredging operation can be executed with accurate dimensions so that everything “fits”.

The last survey will be conducted after the dredging project to show the final result of the operation and for further use for the project sponsor if needed.

Data Analysis and Results

According to the CHS Survey Standards, this will be an Exclusive Order survey, meaning that it will have a horizontal accuracy of 1 metre at a 95% confidence level, and with a depth accuracy of constant depth error (a) equalling 0.15 metres, and factor of depth dependent error (b) equalling 0.0075 metres.

This will be done by keeping to a lower swath width for the multi-beam echo sounders, as the accuracy degrades at higher swath widths. Here, the maximum swath width used will be 120 degrees.

The Sidescan Sonar is not measuring depth at all - it cannot. Instead, it will be using the Sonar echos to create greyscale imagery of features on the waterbed. This can be used to 'see' objects on the seafloor, as well as be used for comparative imagery pre and post dredging. For the processing, the pings from the Sidescan Sonar are received and processed by a computer program that outputs the series of pings in their time-oriented rows in varying shades of grey that correspond to the intensity of the ping (depending on the type of object it bounced back from). What is 'seen' is the acoustic shadow from the object - the lengths of these shadows computed with the Sonar altitude (height of Sonar above seabed) allows the height of the object on the seafloor to be calculated.

For the Multibeam data, a collect-process-collect method will be used. As the data is collected, it will immediately be processed so any gaps in the data can be resurveyed as soon as possible.

The following steps will be used to process the Multibeam data:

First, positioning data from the different sensors will all be merged. Next, any necessary depth corrections will be applied, which will include those related to the draught of the ship being used for the survey, changes in the water level during the survey, and attitude sensor measurements. Then, the heading, pitch, and roll data will be checked so any gaps within this can be removed as well, sound velocity corrections due to refraction errors will be calculated, and any system time latencies addressed. After this, analysis of the time series of the returning signal will be used as a check for the validity of the data, positions and depth data will be merged by applying time and distance offsets. Finally, data cleaning will be used, which will first be done with the use of automatically controlled algorithms known to the industry to be reliable, and lastly a manual data cleaning will be done - this will employ the use of 3D visualization tools in order to be able to notice any remaining outliers or ambiguities in the data set, and correct them as required. For both the Sidescan Sonar and the Multibeam data, note that the raw data must be converted into a usable format before processing. This is done through upload into the computer system.

The results from both of these data sets, once processed, will be survey maps that provide both imagery and depth of the waterbed. These will be used to see where the dredging will take place, how much dredging needs to be done in each part of the harbour, and in the subsequent surveys, how the dredging has progressed, and to confirm that the project was completed as planned.

Budget

Figure A1: Equipment Cost

EQUIPMENT COST						
Equipment		Cost of Ownership	Rental Cost	Cost/Day	Duration of days (3 days per survey)	Cost (cad)
MultiBeam Echo Sounder		170000	\	1000	9	9000
Sidescan Sonar	Tow Fish	50000	\	500	9	4500
	Transmission Cable		\		9	
	Topside Processing Unit		\		9	
Boat		50000	\	500	9	4500
Laptop		3500	\	5	9	45
3 Dry Suits		1500	\	1.5	9	13.5
2 Life Ring Buoys		180	\	0.5	9	4.5
Truck		40000	\	150	9	1350
					Total	19413
46 SURVEY LINES 46 Turns Speed of sound in the harbour ranges from 1421.6 to 1504.4 m/s Mean depth of 13m and maximum depth of 24m						

Figure A2: Personnel Costs

PERSONNEL COSTS				
Members	Pay per km^2 per survey (cad)	Area covered (km^2)	Number of Surveys	Cost (cad)
Licensed Hydrographer	100	27	3	8100
Survey Assistant 1	65	27	3	5265
Survey Assistant 2	45	27	3	3645
Captain	50	27	3	4050
Office Clerk	NA	NA	NA	2000
			Total	23060

Figure A3: Travel Costs

Travel/ACCOMODATION/Safety Training					
Type	Description	Duration(days)	Rate/day	Cost(cad)	Notes
Lodging	Air BNB 3 Bedroom	6	130	780	
Food	Twice a day for 4 crew Members	6	120	720	
Fuel	250 a day for both truck and vessel	6	250	1500	
Safety Training	For the survey Assistants	NA	NA	NA	Captain will provide safety Training
Miscellaneous	Any other expenses that might come up	6	50	300	
			Total	3300	

Figure A4: Total Cost

Total cost (CAD)	
Equiqment	19413
Personnel	23060
Travel/Accomodation	3300
Sub Total	45773
Profit Margin at 30%	13731.9
Total	59504.9

Since our company has most of the equipment available, our costs may seem quite low but we do provide good services as evidenced by our previous projects. Our Multibeam echo sounder does have an INS installed, the specs also include a sound velocity profiler, necessary for determining the speed of sound in the water, it also exceeds IHO special Order. We do have 2 survey assistants who have different rankings in the company. Assistant 1 has been in the company for a longer time and is in the process of obtaining his license as a hydrographer. Assistant 2 is a recent Geomatics Engineering Graduate working to get his land surveyors license. All staff are trained in processing the data including the clerk who will be responsible for some data analysis and preparation of all documentation. The clerk will also be keeping in touch with the company responsible for the dredging and setting up schedules for meetings etc. Our Vessel already has all necessary sensors and equipment installed on it. This usually has to be adjusted based on the location of the survey and the water depth. These adjustments are made before the start of the survey. The truck is mostly for transporting the vessel.

Risks

There are different categories of risk when conducting this hydrographic survey. There are 4 categories of risk we developed.

Human Risks

These risks pertain to the safety of the team and other tourists who are nearby the survey area. Although the team is tasked with safety training, there is still a risk of crew members getting injured by: falling into the water, experiencing motion sickness, fatigue, and stress. There can also be human error during the survey such as improper recording of data and failing to stay on the survey line/missing boat turns. Hamilton Harbour is also a tourist attraction that can interfere with the hydrographic survey. Such as tourists canoeing and surfing during the survey. Due to the possibility of tourists wanting to enjoy their hobby during the survey, it might be necessary to request cutting off access to the harbour to avoid interference.

Equipment Risks

These risks pertain to the equipment used during the survey which can affect the quality of the survey. This can include possible damages to the boat and equipment, sensors malfunctioning, magnetometer and receivers experiencing an offset from its initial position, and IMU not being set properly. These risks require the most attention as they can occur prior to and during the survey.

Environment Risk

This pertains to damages to the environment and hazards to acknowledge in the survey location. This can mean damages to the Harbour through oil spills from the boat/ecological damage, cause of over dredging or improper dredging if the survey is not accurate, tides that can rock the boat and interfere with measurements, and noting the Burlington Lift Bridge. The bridge has a clearance of approximately 5 meters when lowered, if the entirety of the boat exceeds that height and needs to pass under the bridge, there needs to be a request for the draw bridge to be lifted.

Business Risk

These risks pertain to the reputation of the company. This can include the performance of the hydrographic survey, possibility of breaching laws and regulations of Canadian Waters, and ensuring results hold up to Canadian Hydrographic Service standards. The quality of the hydrographic survey can determine if the company will receive more business requests or be regarded as an inadequate company.

<u>Communication with the Project Sponsor</u>

Communication between the team and project sponsor will happen frequently during each part of the hydrographic project (discussed in feasibility phase). It is very important to understand the requirements that the project sponsor defines. Communication allows understanding of the project whether it meets survey standards addressed for the Hamilton Harbour or if the requirements abide by Canadian water laws. Communication between team and project sponsor can be weekly or daily updates depending on the length of the assignment which can be delivered in-person, email/online, or by phone. Each team member will update the project sponsor on findings, next steps, and possibly ask for recommendations. Erin is to report to the project sponsor on what is found in the reconnaissance of the survey area. This can include the mechanics of the Burlington Lift Bridge and an approximate number of tourist attractions. Nadine is to work out a budget that is agreeable between the project sponsor and the company. Ryan is to provide a list of equipment. All drafts and plans of the design phase and survey results are to be submitted to the project sponsor. From there, we can suggest the findings of results in relation to the dredging project such as how much depth/space is allowed. This ensures that the project is being carried through properly in accordance with the dredging project whether it is before, during, or after. Communication can still continue after the project if the project sponsor requires clarification of deliverables or needs help addressing the information of the project to others.

Team Contributions

Ryan	Nadine	Erin
Progress to Date Tasks Left to Do Future Risks Project Management Risks Communication with Project Sponsor Design of Hydrographic Survey	Project Overview Problem Statement and Objectives Budget Specs and Equipment Executive Summary	Project Plan Study Area and Relevant Data Introduction and Scope Data Processing and Deliverables

Appendix

Figure 1: Computation of Footprint Size [7]

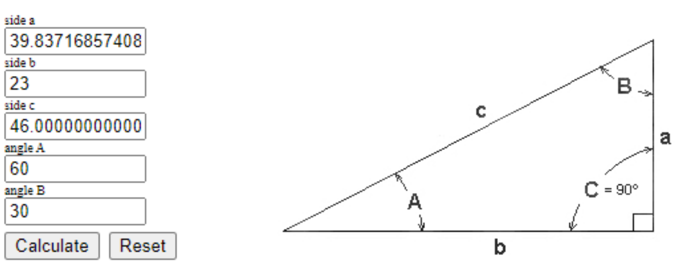


Figure 2: Survey Lines of Hamilton Harbour (blue circle represents start and end)

Figure 3: Check Lines of the Survey

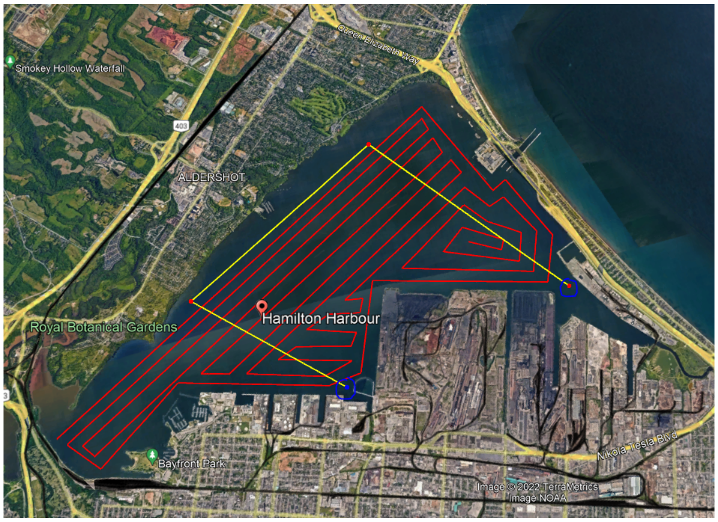


Figure 4: Marsh Area in Hamilton Harbour

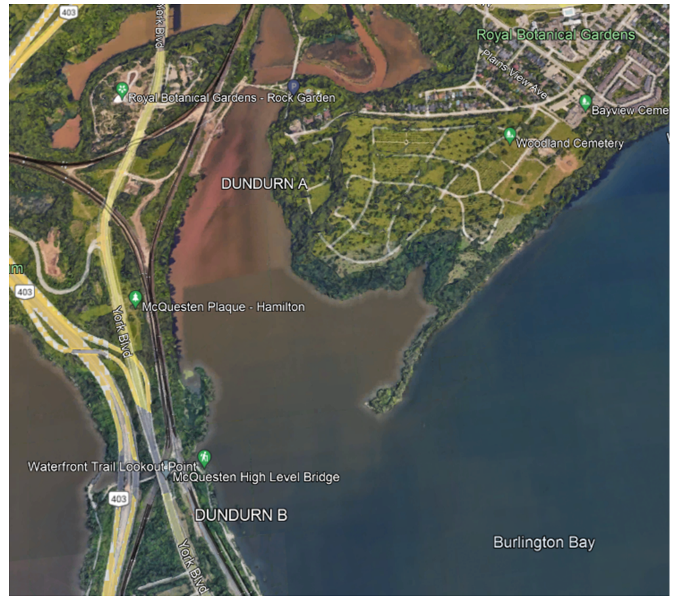


Figure 5: Sections of the Harbour

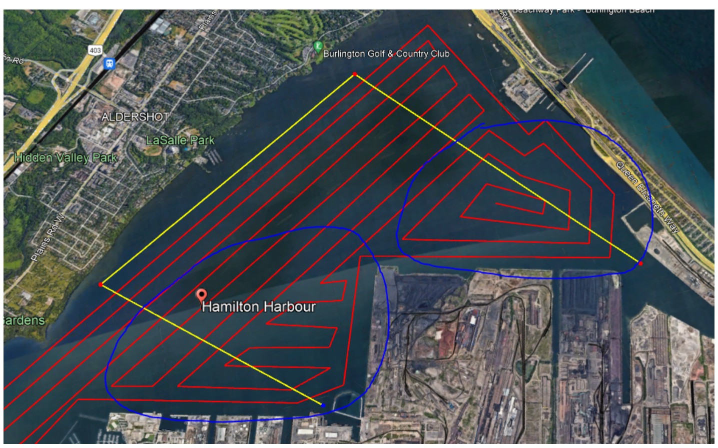
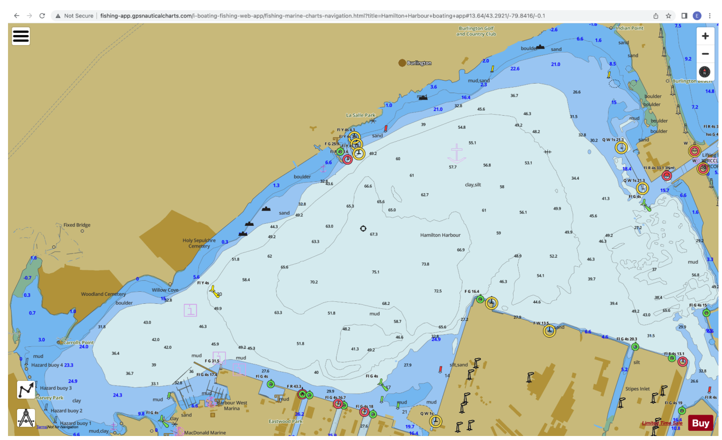


Figure 6: Nautical Chart showing depths in the Hamilton Harbour.



References

Armenakis, C. (2022). Lecture 6: MULTI-BEAM ECHO SOUNDERS. ESSE 4650 Hydrography. Toronto, Ontario, Canada: York University

Armenakis, C. (2022). Lecture 7: UNCERTAINTY MANAGEMENT. ESSE 4650 Hydrography. Toronto, Ontario, Canada: York University

Armenakis, C. (2022). Lecture 10: SIDESCAN SONAR. ESSE 4650 Hydrography. Toronto, Ontario, Canada: York University

[1] Canadian Hydrographic Service. (2021, February). STANDARDS FOR HYDROGRAPHIC SURVEYS. Retrieved April 3, 2022, from https://waves-vagues.dfo-mpo.gc.ca/Library/41034685.pdf

[2] Scuba diving courses in Toronto and shopping. Dive World. (2021, November 9). Retrieved April 3, 2022, from https://diveworld.ca/

[3] I77h - Norbit. (n.d.). Retrieved April 3, 2022, from https://norbit.com/media/PS-200004-7_WINGHEAD-i77h_A4.pdf

[4] Communicatie, F. I. Z. Z. M. &. (n.d.). Klein 4K-SVY professional side scan sonar. Geo. Retrieved April 3, 2022, from https://geo-matching.com/sidescan-sonars/klein-4k-svy-professional-side-scan-sonar

[5] Connecting you to the Waters Edge. Hamilton Waterfront Trust. (n.d.). Retrieved April 3, 2022, from https://www.hamiltonwaterfront.com/

[6] | Teledyne geospatialcaris software. HIPS and SIPS | Teledyne Geospatial. (n.d.). Retrieved April 3, 2022, from https://www.teledynecaris.com/en/products/hips-and-sips/

[7] Trigonometry calculator. (n.d.). Retrieved April 3, 2022, from http://www.carbidedepot.com/formulas-trigright.asp

[8] Hydrographic survey category B course. CIDCO. (n.d.). Retrieved April 3, 2022, from https://www.cidco.ca/en/education-and-training/hydrographic-survey-category-b-course

[9] Swimming lessons - canadian Red Cross. Red Cross Canada. (n.d.). Retrieved April 3, 2022, from https://www.redcross.ca/training-and-certification/course-descriptions/swimming-and-water-safety-courses/swimming-lessons

[10] Hamilton Harbour (marine chart : CA573362). Hamilton Harbour (Marine Chart : CA573362) | Nautical Charts App. (n.d.). Retrieved April 8, 2022, from https://www.gpsnauticalcharts.com/main/ca573362-hamilton-harbour-nautical-chart.html

[11] Great Lakes vertical control - geodesy.noaa.gov. (n.d.). Retrieved April 8, 2022, from https://geodesy.noaa.gov/wp-content/uploads/2018/06/Lippincott1-2.pdf